Report for 2005MI57B: Natural Resources Integrated Information System

Publications

- Articles in Refereed Scientific Journals:
    - Ouyang, D., J. Bartholic, and J. Selegean. 2005. Assessing Sediment Loading from Agricultural Croplands in the Great Lakes Basin. The Journal of American Science, Vol. 1(2): pp. 14-21.
    - Shi, Y., J. Bartholic, A.J. Asher, J-Y Choi, B. Engel, R. Farnsworth. 2005. “An On-line Web GIS-based Hierarchical Watershed Decision Support System for United States,” ISEIS 2004 International Conference, Journal of Environmental Informatics Archives, ISEIS Publication #002, Volume 2 (2004), pp. 838-845.
    - Zorn, T., P.W. Seelbach, and M.J. Wiley 2002. “Distributions of Stream Fishes and their Relationship to Stream Size and Hydrology in Michigan’s Lower Peninsula.” Transactions of the American Fisheries Society 131: 70-85

Report Follows

Project Number: 2005MI57B
Start: 03/01/05 (actual)
End: 02/28/06 (actual)
Title: Natural Resources Integrated Information System
Investigators: Jon F. Bartholic, Institute of Water Research, Michigan State University
Focus Categories: M & P, WQL, MOD
Congressional District: eighth
Descriptors: Data Analysis, Data Storage and Retrieval, Information Dissemination, System Analysis, Geographic Information Systems, Water Quality Management, Watershed Management

Areas of Relevant Research
The management of water resources, appropriate policies, and data acquisition and modeling continue to be at the forefront of the State Legislature's agenda and numerous environmental and agricultural organizations. Our contribution to informing the debate involved numerous meetings, personal discussions, and most importantly, the enhancement of web-based information to aid in the informed decision-making process.

Results and Benefits
Extensive investigation and research is needed to achieve effective coupling of human management needs with geospatial databases and decision support systems to assist better decision-making. Multiple research funding opportunities exist to support linking understanding of various phases of the hydrologic cycle with impacts on water use, management, and conservation. As a result, outstanding opportunities to develop scientific water management skills and techniques for the 21st Century are clearly within reach.

Development of geospatial decision support systems complement and build on the extensive scientific knowledge of the role of the hydrologic balance in the functioning of dynamic ecosystems. Based on current development of geospatial databases and modeling systems, a model of the hydrologic balance for the state can be developed to assist water management and conservation. By incorporating extensive geospatial data with the analytical capacity of decision support systems, university researchers are providing decision-makers and managers with a more refined understanding of the hydrologic cycle and water balance functions at watershed and statewide scales.

Our USGS investments over the past two years led to a two-year $540,000 grant from the Great Lakes Protection Fund awarded to Michigan State University and the Institute of Water Research (IWR) for a project entitled "Restoring Great Lakes Basin Waters Through the Use of Conservation Credits and an Integrated Water Balance Analysis System." The IWR is responsible for coordinating and collaborating multidisciplinary teams from various organizations including the World Resources Institute, Institute for Fisheries Research of the Michigan Department of Natural Resources, Public Sector Consultants of Lansing, US Geological Survey District Office, and MSU Departments of Agricultural Economics, Biosystems and Agricultural Engineering; Geography, Civil and Environmental Engineering; and the Community, Agriculture, Recreation and Resource Studies (CARRS).

The project will integrate three systems --Water Conservation Credit, Water Balance Analysis, and the User Assistance Interface, into a single Water Conservation Credits Implementation package. Large water users, including municipalities, corporations, and irrigation users, who are considering major new withdrawals can benefit from the Water Conservation Credits Implementation package by being able to access information on the watershed in which they have an interest, and use this information in their management decisions to guide potential conservation transactions. Individually, the Water Conservation Credits System provides analyses to support the development of an innovative system of water conservation credits which will help policy makers manage water resources to meet the demands of water uses, conservation, and the improvement of ecological sustainability. The Water Balance Analysis System integrates three existing hydrological models that incorporate surface, groundwater, and stream aquatic ecosystem models. The User Assistance Interface System couples the hydrologic models with spatial data to allow a decision maker to create various scenarios for management of water resources in Michigan and the Great Lakes Basin. Combined, these systems can be used to assess the ecological vulnerability of watersheds, the impacts of wells on groundwater levels, river and ecosystems, the effectiveness of conservation practices and associated water conservation credits, and other issues. State agencies in the Great Lakes Basin who are responsible for the improvement of water resources and the health of the Greater Lakes Basin ecosystems can use the system package to support development and implementation of state and regional water management policies. Products will be designed as simple online tools by integrating information and models with appropriate interfaces to the water analysis system. The entire study process is guided with inputs from an Advisory Team composed of leaders from a wide set of interest areas.

The policy impact of this project has been immediate, significant, and perhaps even profound. Our project influenced the final shape of landmark legislation signed into law February 28 that establishes a comprehensive framework for the management of water resources in the state of Michigan. Moreover, findings and results from our project will provide policy-relevant scientific research and new tools to inform the implementation of state water policy, including making future policy recommendations by July 1, 2007 specified in P.A. 34 (2006) for the sustainability of state groundwater use, development of sustainability indicators to evaluate sustainability of state groundwater use, determining whether certification requirements are needed for groundwater withdrawals to assure conformance with Annex 2001, determining whether conservation programs should include mitigation of adverse impacts of water withdrawals on state waters and water-dependent natural resources, and other critical areas. Equally important, this state legislation puts Michigan in accordance with the provisions of the Great Lakes Charter Annex 2001 so that the innovations in our development of state water resource decision-making and related tools will potentially have application across the Great Lakes Basin. Many of our Advisory Team members contributed to the passage of this legislation and will be involved in the implementation of this new comprehensive water policy framework. Our Advisory Team provided an excellent conduit through which the knowledge and development of our project has informed the legislative process and will inform the policy making process in the future.

IWR and its partners are expected to participate in the design of a water withdrawal assessment tool as specified by the P.A. 34 (2006) that will incorporate state-of-the-art and real-time scientific research to guide and assist the permitting of large-capacity water withdrawals. This assessment tool must be designed to evaluate the impacts of water withdrawals on nearby streams and/or aquatic-dependent natural systems and whether a proposed withdrawal may cause

an adverse impact on state waters or aquatic-dependent resources. We envision a major role for our Project Team, in cooperation with other researchers and stakeholders, to develop this assessment tool by using the results from the preliminary development of computer sub-models developed for this project.

In addition to a significant role in developing the assessment tool, we anticipate a major role in using the results of our project for application in a new water use conflict resolution process. Those seeking permits for large quantity withdrawals are encouraged by the new legislation to establish a Water User Committee for that permit to evaluate current water resources, water uses, and trends in water use in the watershed and assist in long-term water resource planning in the watershed. Water User Committees will include all water withdrawal registrants, water withdrawal permit holders, and local government officials in the watershed. Solutions to water use conflicts developed by these committees could include water conservation offset credit as pioneered by this project. While this committee process is not required, it will certainly behoove any permit seeker to follow this process in light of Michigan's recent history with time-consuming court cases and formidable public opposition to large water withdrawals.

The new legislation also calls for the state Department of Environmental Quality (DEQ) to use "clear and convincing scientific evidence" in determining whether adverse resource impacts "are, or are likely, to occur from one or more large-quantity withdrawals in the watershed." The DEQ will be responsible for notifying the watershed Water Users Committee or meeting with water use registrants and water withdrawal permit holders to attempt facilitation of an agreement for using voluntary measures to prevent adverse resource impacts.

We anticipate that the findings regarding our voluntary, water conservation offset credit approach may be directly applied to create a science-supported scheme that accommodates all water users and avoids costly, time-consuming legal conflicts and divisive dissatisfaction in the community. By integrating our data into a readily-usable and web-accessible system for Water User Committees, timely and valuable information will be delivered to those who need it most. Future opportunities appear abundant for assisting the local watershed conflict resolution process and for creating viable options, including offsets and conservation credits, to prevent adverse resource impacts. These scenarios will be supported by science-based research supported by the GLPF.

The bottom line shows a unique convergence of our NIWR/USGS and the Great Lakes Protection Fund project with the implementation of recently-enacted state legislation and with the next phase of state policy making. As prescribed in recent legislation, a set of policy recommendations addressing the sustainability of groundwater will be submitted by the Groundwater Conservation Advisory Council (GCAC) July 1, 2007 and the GCAC process needs to be informed by hard science and knowledge of state water resources and watershed management. In addition, the Groundwater Conservation Advisory Council is responsible for guiding the overall implementation of the legislative mandates for related water policy development as well designing the water withdrawal assessment tool. As some members of our project Advisory Committee serve on the Groundwater Conservation Advisory Council, a robust linkage provides an important mechanism for the Institute's role in developing the assessment tool and assisting in conflict resolution processes.

Our web-based offerings continue to expand. A Nation-Wide Digital Watershed web site has been developed to allow individuals from across the United States locate themselves by using their address, watershed, or by regional areas established by the EPA. The illustration shows the

software developed in the IWR that can be applied to a national situation. The data used in the system was acquired from EPA Basin data via the web. The site for Michigan allows users to zero-in on the eight-digit watersheds and then down to the 12-digit watershed system known as "Know Your Watershed." A special web site was prepared for the Kalamazoo Watershed project to assist them in prioritizing and developing a watershed management strategy. A substantial effort has been completed using all the digital orthoquads (DOQQ) available across Michigan. These have been acquired and seamlessly integrated with quality control and compression algorithms. This information now serves as a backdrop on our "Know Your Watershed" web site. The DOQQ integrated data set is also used as a backdrop for soils information on IWRs new EZMapper web site. This site was specifically designed to aid with Comprehensive Nutrient Management Plan development for agricultural farms throughout the state. The system allows downloading of software to outline fields and utilize the available data. Recently, automatic extraction procedures were added to Digital Watershed to incorporate DOQQ's imagery on the fly across the U.S. from Microsoft Terra Server.

IWR, Purdue University, and EPA Region 5 organized a workshop that examined web-based tools for land use and watershed planning. The Mapper is now under way to serve-up these tools across all states within Region 5, along with obtaining the same data that would be common for each state.

What is the Midwest Partnership for Watershed Management Decision Support Systems?
In April 2002.US EPA Region 5, Michigan State University, and Purdue University co-hosted the Midwest Web-based Spatial Workshop in Chicago.
Various decision support and GIS systems were demonstrated, and experiences and "wisdom" learned were shared amongst practitioners. In attendance were:

- State, Federal, and Tribal water resource managers
- Land Grant University Extension community
- Watershed managers and local government representatives

The goal of the Midwest Partnership for Watershed Management Decision Support Systems is to develop, promote, and disseminate web-based spatial decision support systems to help manage watersheds in the Midwest.

One outcome of the workshop was a commitment by the participants to advance Region-wide web-based decision support efforts for watershed management. The Midwest Partnership for Watershed Management Spatial Decision Support Systems is another outcome of the workshop. ***(More about the Workshop, its objectives, and attendees).***

Local watershed management forms the basis for continued economic development and environmental improvement in the United States. Success depends on an integrated approach that brings together scientific, education and training advances made across many individual disciplines and modified to fit the needs of the individuals and groups, who must write, implement, evaluate, and adjust their watershed management plans. The purpose of our 5-year project is to:

- Improve the management of watersheds in Region 5 through the development, promotion and use of a web-based, user-friendly, geo-spatial watershed management data and decision support system (WMDDSS).
- Help set the standard for other watershed management programs across the country.

The partnership includes:
- Indiana Department of Environmental Management
- International City/County Management Association
- Michigan State University, Institute of Water Research
- Purdue University - Agricultural and Biological Engineering, Forestry and Natural Resources
- State University of New York at Buffalo
- University of Wisconsin Extension
- U.S. Environmental Protection Agency, Region 5 - Office of Public Affairs, Water Division and the Office of Information Services
- Wisconsin Department of Natural Resources

New and Future Development for Digital Watershed

As a key technical component of Midwest Spatial Decision Support System Partnership, the Institute of Water Research's Digital Watershed (DW) website has been recognized by EPA Office of Research and Development as an important environmental computing portal for a suite of EPA's environmental decision support tools. Funding is underway to support the future development of DW to achieve this goal. The first step is to integrate EPA's ATtILA (Analytical Tools Interface for Landscape Assessments) tool into DW and provide watershed comparison function at 8-digit watershed level. This work will lay a solid foundation for the integration of other EPA decision support tools such as Regional Vulnerability Assessment Program's EDT (Environmental Decision Toolkit).

The Institute of Water Research was also awarded a grant by the US Army Corps of Engineers Chicago District to create a tool that integrates a GIS-based sediment runoff predictive tool, MUSLE (Modified Universal Soil Loss Equation), into Digital Watershed (DW) and the Long-Term Hydrologic Impact Assessment (L-THIA) system and its associated EQIP tools. The resulting modeling and decision support tool will be easily accessed and used by a wide variety of expertise levels in determining the effects of development and different agricultural practices to the sediment loadings within two tributaries to Lake Michigan in Northwest Indiana; Burns Ditch/Little Calumet East Branch and Trail Creek. We've recently completed EQIP and the preliminary MUSLE integration on the project. In the near future, users will be able to model different BMP scenarios using this online tool.

Another new function that's already up and operational on Digital Watershed is the Google Map and Google Earth interoperability capability. Users can explore their own watersheds on Google Maps or Google Earth by simply click a button on Digital Watershed interface. We've received a lot of positive feedbacks on this new development.

The web-available Mapping is used extensively in IWRs Virtual Watershed Management courses. This past year we offered all four 3-credit modules of Watershed Management each

semester in the series for Certification. There are now over 120 students registered per year in these courses.

Our work with the Michigan Department of Environmental Quality (DEQ) continues at a high level. With funding, between $700,000 and $1M dollars per year, it is largely the result of the Institutes' responsibilities being recognized statewide. This cooperation has led to a major role coordinated by the USGS Michigan Water Science Center and IWR; details follow. The U.S. Geological Survey (USGS) and Michigan State University (MSU) are leading a cooperative effort to assist Michigan Department of Environmental Quality (MDEQ) in meeting the requirements of Section 32802 of Public Act 148. Interim products, task-specific work plans, appropriate review and comment periods, and quarterly project meetings, or a t more frequent intervals, as requested by MDEQ or necessitated by project accomplishments.

The project activities are organized according to the parts of Section 32802. All project activities described below will be part of a team effort including MDEQ, USGS, and MSU. All activities, however, have an identified lead or co-lead role. Product completion dates, as well as timeframes for completing sub-activities necessary to meet completion dates, are identified. Also included is $1,150,000. MDEQ funds of $900,000 will be split equally between USGS and MSU. USGS Cooperative Water Program funds of $250,000 will be added to the USGS component of the project.

(a) Location and water yielding capabilities of aquifers in the state
(b) Aquifer recharge rates in the state
(c) Static water levels of groundwater in the state
(d) Base flow of rivers and streams in the state
(e) Conflict areas in the state
(f) Surface waters, including designated trout lakes and streams, and groundwater dependent natural resources, that are identified on the natural features inventory
(g) The location and pumping capacity of all of the following: (i) industrial or processing facilities registered under section 32705 that withdraw groundwater, (ii) irrigation facilities registered under section 32705 that withdraw groundwater, (iii) public water supply systems that have the capacity to withdraw over 100,000 gallons of groundwater per day average in any consecutive 30-day period
(h) Aggregate agricultural water use and consumptive use, by township

Our strategic plan for the Michigan Institute of Water Research (IWR) over the next five years has been developed and submitted to the Director of the Michigan Agricultural Experiment Station, the Dean of the College of Agriculture and Natural Resources at Michigan State University (CANR-MSU), and subsequently to the Office of the Vice President for Research and Development. The strategic plan outlines a number of key strengthening components for the MI IWR. (1) The affiliate positions within the Institute. These positions might be 25% time in the IWR and 75% in a discipline department. A group of affiliates would greatly strengthen the discourse relative to problems and techniques for solving them as well as the information dissemination. Additionally, adjunct faculty are generally somewhat less involved but enhanced mutual awareness of our programs would greatly enrich the pool of expertise of water scientists from which we could draw upon in order to more effectively address issues of concern within IWR. (2) Enhanced funding for the IWR: New Fiscal Support: Facilitating a competitive grants

program in the water arena has been proposed. Preliminary discussions relative to the plan are leading to the strong possibility of adjunct and joint affiliate positions, but any new funding is on hold in light of the State's budget difficulties.

Related Research

We continue to obtain synergistic impacts by closely aligning our efforts with support from such organizations as the Corps of Engineers, USDA, US Forest Service and numerous other agencies and NGO's. This past year we received a grant from the Corps of Engineers for $75,000 which involves estimating sediment delivery from each of the eight-digit watersheds within the entire U.S. side of the Great Lakes Basin. This database is not only of value to the Corps in prioritizing their efforts but also provides us with a broad set of additional information that we can use in other programs, and for assisting with the prioritization of high risk areas for erosion throughout the region. USDA funds involve a coordinating effort of outreach and research among all states within the EPA Region V. IWR personnel are partially funded through this regional project which coordinates and facilitates the communication of research methodologies, approaches, and results from our research and aides with region-wide outreach programming.

Training Potential

New graduates and graduate training continue to be a high priority of IWR. Unfortunately, graduate stipends have increased to the extent that a 1/2 time graduate student with fringe benefits, requires from $35,000-$45,000 (per year). We will make every effort to continue incorporating graduate students but with the high cost, it is increasingly difficult to employ more than a few students at any given time. As part of our partnership philosophy, we have jointly supported numerous graduate students with other departments and units on campus.

Special Project

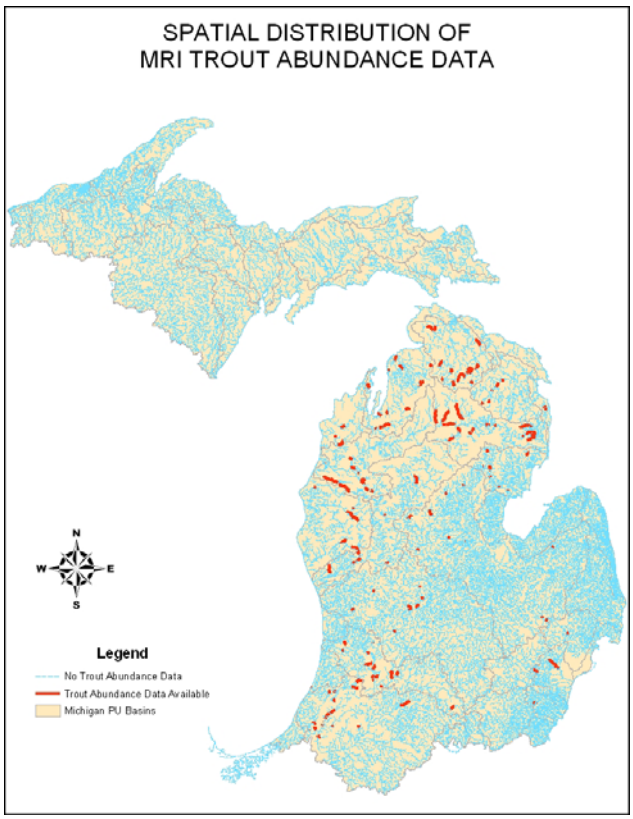
State: MI
Start: 03/01/05 (actual)
End: 02/28/06 (actual)
Title: 1.3 Ecological Modeling
Project Type: Research
Focus Categories: Water Quality, Water Quantity, Models
Research Category: Water Quality
Keywords: Ecological Modeling, Water Temperature and Flow Modeling, Fish Modeling, GIS Framework, Catchment
Principal Investigators: Lizhu Wang, M.J. Wiley and Paul Seelbach

River Fish Models

- *Fish Selection Objective:* Identification of fish species that are sensitive to water temperature and flow variations. The development of predictive models for only those identified fish species because only fishes that are sensitive to changes of temperature and flow are relevant to the GLPF objective.

- *Environmental Variables Objective:* Identification of key environmental variables most influential to fish distribution and abundance.

- *Develop species-specific models:* Explore different approaches to predict the occurrence and abundance of species. One potential method is multiple linear regression.



Fish Selection

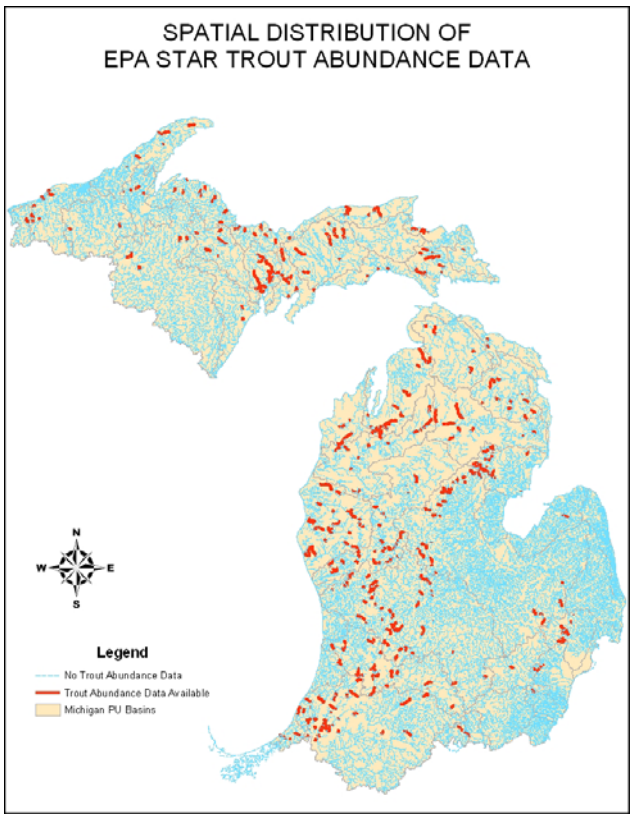
Trout species (brown trout, brook trout, and rainbow trout) were selected as the fish species of interest in the GLPF study. The selection was due to trout's non-migratory nature, relatively narrow thermal tolerance, availability of historical abundance data, and the importance of the fishery. This selection has directed the scope of all further research.

Environmental Variables

Database Creation

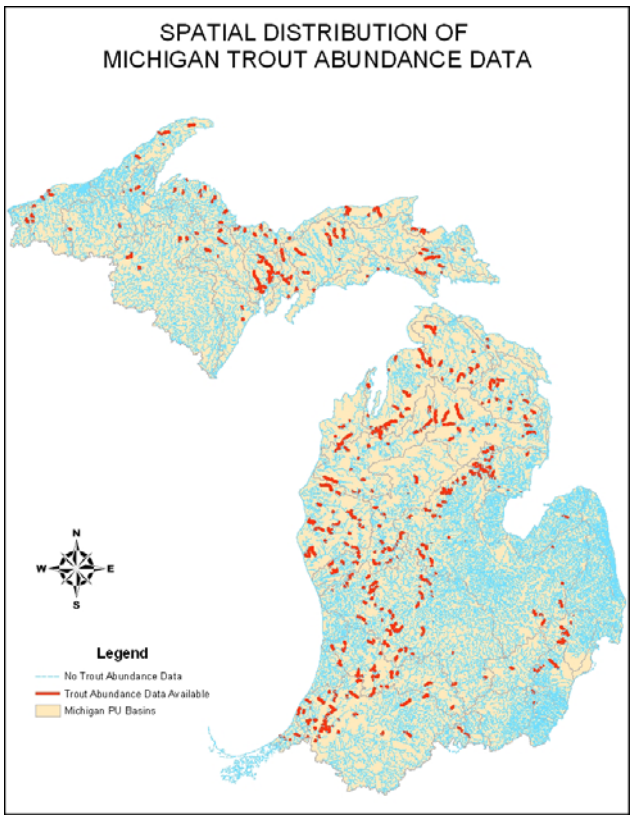
Fish community data – Fish community data from about 800 stream sites with length ranging from less than 100m to greater than 1,000m were gathered. The fish abundance data are from two data sources: Michigan

Rivers Inventory (MRI) and EPA STAR project (STAR). The MRI sites have standardized abundance estimates for 384 sites throughout Michigan, which were sampled using rotenone or multiple run electro-fishing. Because some sites were on the same inter-confluence stream reach, only 256 unique reaches were associated with modeled flow discharge and trout data (see left).

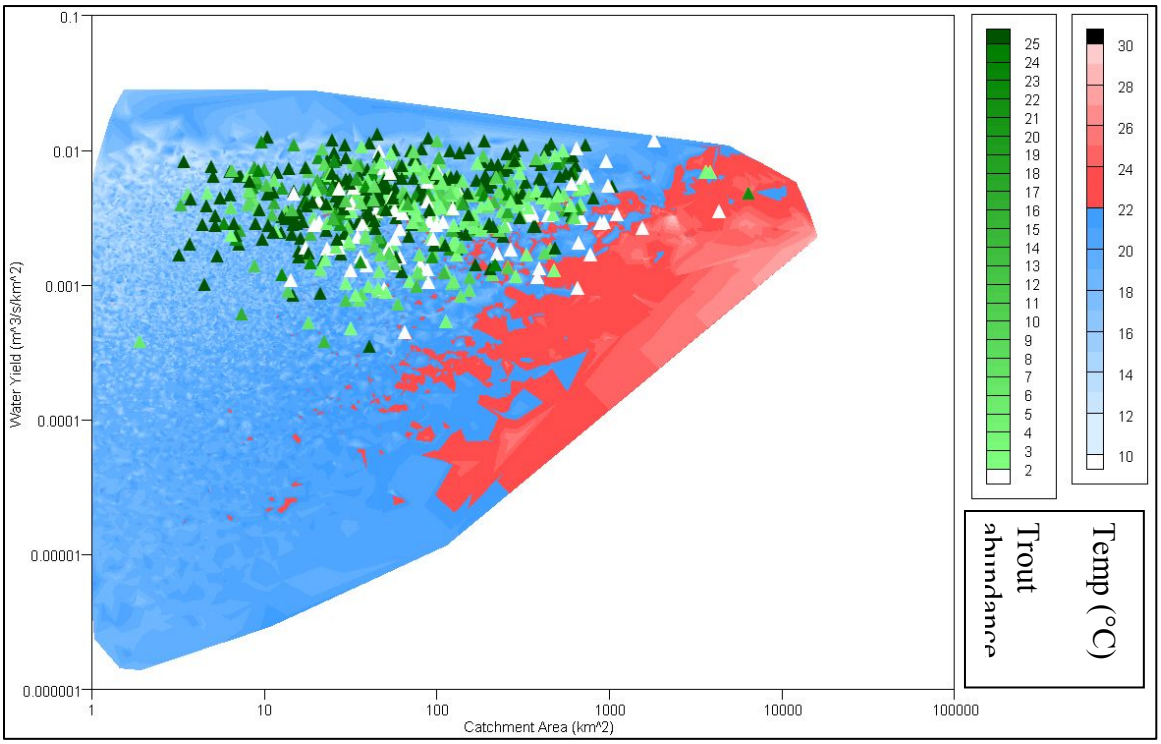


The STAR fish data consisted of 793 sites throughout Michigan. Among them, 715 sites were associated with trout data, unique reaches, and modeled discharges (see right). The majority of these sites were sampled using single-pass electro-fishing. In order to combine fish abundance values to create a larger database, it was necessary to standardize the abundance data between the MRI and STAR databases.

As this study focused on trout populations, stream reaches with trout abundance data were selected, providing 547 sites for analysis (see below). Abundance data for brown trout, brook trout, and rainbow trout were grouped together to increase the power of analyses. Additionally, previous cluster analysis work by Zorn *et al* (2002) showed a close clustering of these trout species into two overlapping fish guilds along the axes of water yield and watershed area.



The best fit transformation was using a linear regression between the MRI and STAR databases after standardizing the unit of measurement to the number of individual fish caught per 100 meters of sampling stream length. The more standard unit of fish individuals per square meter was not possible to calculate, since many sites lacked sampling width measurement. A slightly stronger regression-based transformation would have been possible by standardizing each site from the STAR and MRI databases based on deviations from standard normal, and creating a set of unitless measures. However, the results of such a transformation was deemed to be less useful in providing a metric of potential trout abundance.



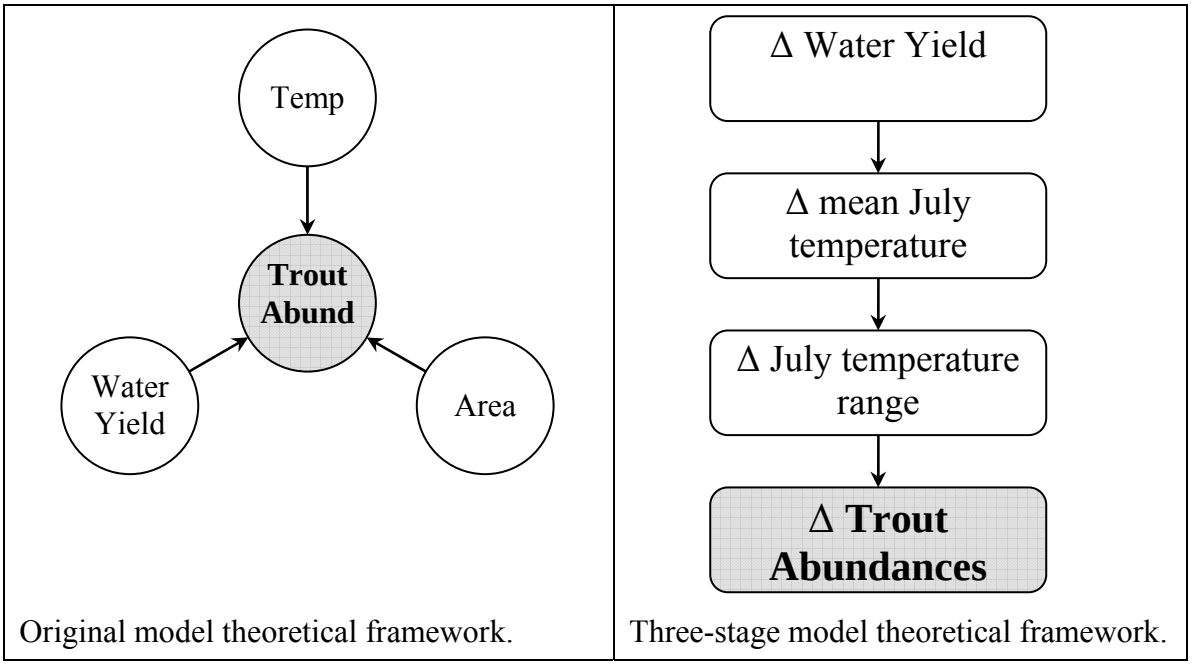
Development of Fish-Flow-Thermal Model – The assessment of trout abundance based on temperature, water yield, and drainage area confirmed that trout were confined to the streams with high yields, usually smaller- to mid-sized streams, and relatively low July temperatures (see above).

The initial multiple linear regression model linking water yield, drainage area, water temperature, and trout abundance was not sensitive to relatively small base flow changes in stream reaches with large catchment areas, or regions with initially high values of water yield due to log transformations issues; a proposed decrease in discharge in a river with a high water yield due to regional pumping would appear to cause little change in temperature, and therefore little impact to trout.

The initial assessment of trout abundance and temperature did not show a strong relationship, since the use of mean July water temperature did not assess the daily temperature stability of any particular site. It was felt that the inclusion of temperature stability would increase the predictive capability of trout abundances, especially at their upper thermal tolerance limits.

The initial multiple linear regression model linking water yield, drainage area, water temperature, and, due to log transformations issues, trout abundance was not sensitive to relatively small base flow changes in stream reaches with large catchment areas, or regions with initially high values of water yield.

To try and ascertain daily temperature stability, additional work explored the possibility of dividing the original single model into a series of three consecutive models (see below). The first model was intended to predict changes in July mean water temperature based primarily on changes in water discharge. The second model would predict temperature stability also based on changes in discharge. The third model would predict trout abundances based on the altered temperature stability and July mean temperatures. It was our hope that these statistical models would incorporate additional climate and landcover parameters and could be used to



Original model theoretical framework. Three-stage model theoretical framework.

quantitatively describe the temperature changes resulted from base flow changes from either ground water withdrawals or BMPs.

Stream Temperature Collection and Analysis – In order to start an assessment of temperature stability, records of July temperatures from a total of 556 temperature sites were obtained from Michigan's Fish Collection System and from regional DNR biologists. The data had been minimally collected for one year, although some sites had up to three-year's of data. The overall dataset spanned the summers from 1993 to 2005. These temperature data were quality-checked and summarized into daily means, minimums, and maximums for the period when the data were collected. All the temperature data sites have been linked to the stream reaches where stream base-flow yield and other landscape variables were predicted or gathered using GIS tools. Summer temperature means and temperature fluctuation means were calculated for each site. Modeled mean July temperatures for all Michigan stream reaches were used where no measured temperatures were available.

Prediction of Mean Temperature Changes – Because water temperatures are strongly influenced by water yield, we have attempted to predict the mean July temperature based on the water yield and other related variables. A linear regression model based on changes in yield within the 539 trout streams with available abundance data were used to examine the amount of temperature change expected due to changes in water yield. The model produced was not in satisfactory form to meet our objective. We are continuing the process of improving the predictive capability of this model.

Prediction of Mean Daily Temperature Stability – Because trout presence and abundance are not only determined by mean water temperature, but also determined by temperature variation, we attempted to develop a model that could be used to predict daily temperature ranges. A multiple linear regression model based on parameters of modeled temperature, watershed area, and stream segment slope regressed against 216 summarized measured temperature ranges was used to create a set of modeled mean daily temperature ranges.

Modeled daily temperature ranges were not significantly different from the observed daily temperature ranges. Using this initial set of modeled temperature ranges, another regression was done to estimate the magnitude of the changes in temperature range due to expected changes in discharge within the 539 trout streams used in the previous section. We are continuing the process of improving the predictive capability of this model.

One current concern is the positive correlative relationship between increasing daily temperature range and trout abundance. Several different methods of statistically isolating the upper bound thermal preferences in trout are being explored, since the inclusion of temperature stability was due initially to a concern of temperature preferences in streams with trout-marginal temperatures.

Application of Multiple Linear Regression Model

Using an expected value of a 1.5 cfs decrease in stream discharge due to regional groundwater pumping provided from the surface and groundwater modeling teams, the changes in temperature and temperature range were modeled using the methods outlined above. The changes in mean temperature and daily temperature ranges were added to the base modeled values. Increases in mean daily temperature and daily temperature ranges were found to be slightly, although not significantly, increased due to pumping.

Using the modeled temperature changes, a first estimate of expected maximum trout abundance was created based on changes in modeled temperature using linear regression. Inclusion of the temperature flux variable did not work as expected, and was been excluded. In all areas, maximum expected trout abundance had decreased slightly, but not significantly based on the current power of the model. We are continuing to increase the predictive capability of this model.

Reference

Zorn, T., P.W. Seelbach, and M.J. Wiley 2002. "Distributions of Stream Fishes and their Relationship to Stream Size and Hydrology in Michigan's Lower Peninsula." *Transactions of the American Fisheries Society* 131: 70-85